Mini Project: Iris Detection (Localization)

Abstract:

Until now, iris recognition has been used in many fields, for example, security based application employ biometrics to ensure the identity of an individual. The iris is the most accurate biometric to date. Iris localization is one of the most important steps in iris recognition system and determines the accuracy of matching. A failed localization will lead to incorrect iris segmentation and eventually to poor recognition. Iris is nearly circular regions, basically the annular region between pupil and sclera, which is surrounded by eyelids and eyelashes and contains intricate details and are difficult to process. We propose 2 method in which iris can be localized. We use the UBIRIS database for the proposed methods.

1. **Hough Circles method:** We obtain the center of the iris and its radius using the Hough Circle transform.
2. **Convolutional Neural Network method**: A CNN network is used as a regression model to obtain the center of the iris and its radius. Only occlusion-free images of UBIRIS database have been considered for training.

In both the methods, we obtain the center of the iris and its radius, assuming the iris to be a circle. We use OpenCV to plot the circle around the iris on the original image. Experimental results show that CNN method gives good performance under different illuminations as well.

Introduction:

Biometrics based person identification is getting popular due to its accuracy and high reliability. During the last few decades many biometric identification techniques such as those based upon voice, fingerprint, signature, face, retina and iris have been introduced. Human iris is a circular area in the eyes, which is meant for managing the size of the pupil so as to control the light reaching the retina. Iris is one of the prominent unique characteristics of human, which can distinguish between the humans. The conventional iris patterns are randomly generated after almost three months of birth and it is reported that they are not changed all the lifelong. It possesses rich texture which offers a strong biometric cue to recognize individuals. It is because of this nature; iris is being utilized as a standard biometric for many security-based applications. Iris recognition is to recognize a person by using unique iris patterns, which exist in iris region between white sclera and black pupil. As public security and safety demands are increasing every day, it is obligatory to have secure identification. Thus, it is very important to develop an effective and accurate iris recognition system. Iris recognition shows good performance for accuracy and safety compared to other biometrics such as face, fingerprint, voice recognition and so on. Also, it is non-contact method and user's refusal feeling is small compared to other contact method such as fingerprint and hand vessel recognition. Iris recognition is comparatively new and considered as highly fool proof due to the fact that it cannot be artificially copied and remains same during a person's life time. Generally, an iris recognition system can have four subsystems 1. Image acquisition. 2. Segmentation. 3. Normalization and iris code generation. 4. Comparison and recognition. Localization is the most important part of any iris recognition system, which is related to the detection of the exact location of the iris in an image. The successful extraction of iris drives the iris recognition system through the phases such as pre-processing, feature extraction and classification. Different techniques are reported in literature for locating the iris. Most techniques are circular-edge based techniques, which mainly involve morphological and geometrical operations, and histogram-based techniques, which use the histogram as the features and hence the computational complexity is more. Edge detection is one of the important factors in detecting iris for both these types of techniques. Some of the Deep Learning algorithms are also proposed for the iris detection, which involve the Convolutional Neural Networks (CNN). These techniques detect iris without any predefined rule set.

We implemented 2 methods for iris localization under the assumption that the iris is of a circular shape. First, we implement Hough Circles method, which localizes the center of the iris and the radius of the iris on the basis of the geometry of the eye. We also implemented a CNN based regression model to locate the iris. The well detected iris information from the Hough Circles method is used for training the network. While testing, the CNN outputs the center and the radius of the iris. The next step is to draw the circle that describes the iris borders. This is done with OpenCV. We experimented our approach using images from UBIRIS database that incorporates images with several noise factors. However, as our model does not consider the closed eyelid images for training. Therefore, it outputs a circle for the images with the closed or partially closed eyelids.

Proposed Method:

Method 1: Hough Circles Method

This method tries to exploit Hough circle detection technique to detect the iris. The steps are given below:

1. **Grayscale conversion**: The image is read out and converted to grayscale.
2. **Thresholding**: To-zero thresholding technique is used and all pixels below 127 are set to 0. This process highlights the iris part of the image, which is predominantly black. To-Zero thresholding can be mathematically expressed as:

$$\textit{thresholded\_img}(x,y) = \textit{source\_img}(x,y); \quad \text{if } \textit{source\_img}(x,y) > \textit{Threshold}$$

$$= 0; \qquad \textit{otherwise}$$

3. **Image smoothing:** Median blur technique with a window size (13,13) is applied, and the image is smoothed out. Smoothing removes any white pixels within the iris, and converts it to a uniform continous black region. Median blur finds the median of all the pixels within the window, and the center pixel is replaced by the median value.
4. **Hough circle detection**: Hough circle detector is deployed in an attempt to detect the circular iris region present in the median filtered image. Hough gradient method, with radius threshold between 35 and 70 was used. This will give us the radius and the center of the iris.

Method 2: Convolutional Neural Network method

A Convolutional Neural Network (CNN) was used as a regressive model, in an attempt to detect the location of iris. The model will return information about the bounding circle, i.e center_x, center_y and radius. We train the model with images and ground truth bounding circle, which uses mean squared error to calculate the loss between the bounding circle and the ground truth.

The steps include:

1. **Dataset Preparation**: The model was designed to output the following parameters -

    a. Center of the iris (X and Y coordinate)

    b. Radius of the iris

This information was to be manually extracted from the image and stored. We used the results obtained from the previous Hough Circles method for this process. Images which generated good results were separated, and these images were used for training the model, and it was tested on the remaining images.

The input tensor: All training images were stacked on top of each other and a tensor of shape (Nx200x150x3) was fed at the input, where N is the number of images.

The output vector: The neural network outputs 3-dimensional vector for each image, and the output matrix will be of shape (Nx3).

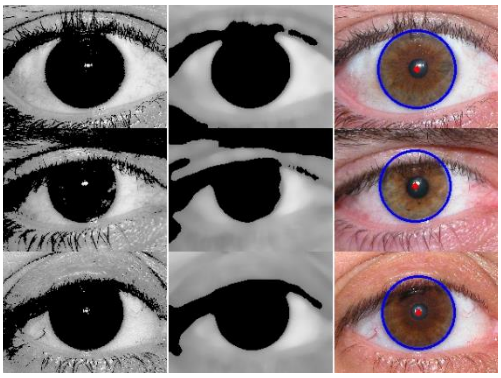
2. **Training the CNN (for 10 epochs)**:

- Images of shape 200x150x3 was normalized and fed as a 3 channel input to the network.
- The first convolutional ReLu layer consisted of 32 filters of square shape (3x3 size, stride=1x1). Max pooling was applied with a pool shape of 2x2 and a stride of 1x1
- The second convolutional ReLu layer consisted of 64 filters (3x3 size, 1x1 stride) and max pooling (2x2 size and 1x1 stride).
- The third convolutional ReLu layer consisted of another 64 filters (3x3 size, 1x1 stride) and max pooling (2x2 size and 1x1 stride).
- Further processing was done through a fully connected hidden layer of 64 ReLUs and an output layer of 3 filters.

Experimental Results:

Method 1: Hough Circles Method

The results were good for images with no eyelid occlusions, under good lighting. Some images with considerably good results are:



(a) (b) (c)

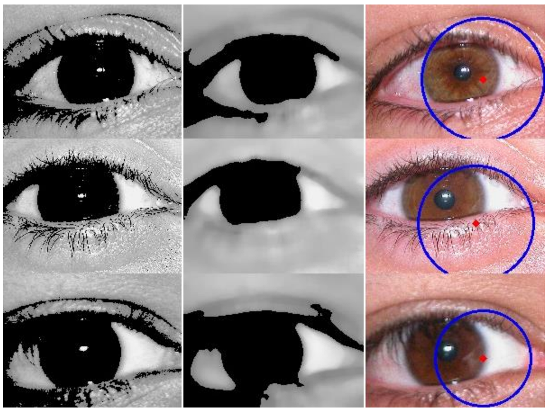
Fig: 1 – (a) Thresholded image (b) Median Filtered image (c)Detected iris location

However, when there is occlusion, this method failed to detect the iris. Few examples are given below:

(a) (b) (c)

Fig: 2 – (a) Thresholded image. (b) The smoothed out iris are not circular in shape, hence the detection fails. (c) The method failed to detect the iris.

Also, when there is considerable noise in the image from eyelashes, skin and other factors, the detected iris locations deviated from the ground truth locations. Some examples are:



(a) (b) (c)

Fig: 3 – (a) Thresholded image. (b) The noise from eyelashes and skin are magnified during the smoothing process leading to incorrect detection. (c) The detected locations are incorrect.

Method 2: Convolutional Neural Network method

CNN method gives very good results in different illuminations. Some of the examples are:

Fig: 4 – Detected iris for different illuminations.

The iris is well detected for the eye images with eyelid occlusions as well. Some examples are shown below:

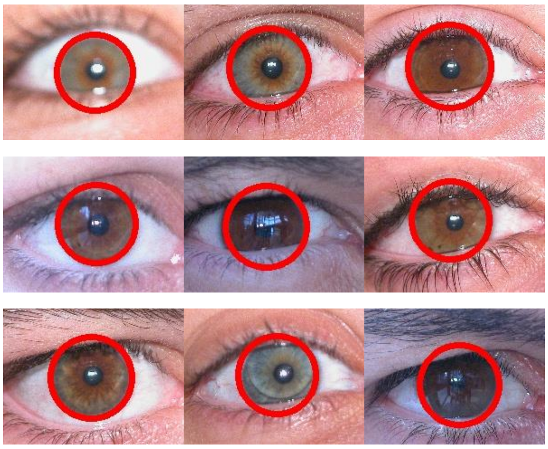


Fig: 5 – Detected iris with eyelid occlusions.

However, when the eyes are closed, the CNN method still detects a circular iris. The erroneous detections are shown below:

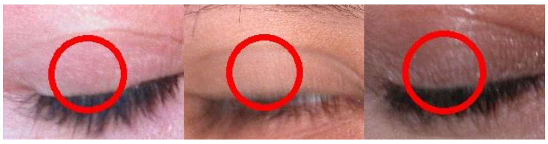


Fig: 6 – False iris detections.

Advantages:

Method 1: Hough Circles Method

Hough Circles method is computationally very simple. It doesn't require huge data for training as there is no machine learning involved. It is scale independent.

Method 2: Convolutional Neural Network method

CNN method gives significantly accurate iris locations. It is robust to illumination variations, noise, and occlusions by eyelid and eyelashes as posed by the UBIRIS dataset. We do not need to manually prepare the dataset for training the CNN based model, as we used the centers and radii information from the Hough Circles method.

Disadvantages:

Method 1: Hough Circles Method

Hough Circles method doesn't give very accurate results. It is highly sensitive to the variations in the contrast of the image, noise, and eyelash and eyelid occlusions. This method assumes iris to be a perfect circle, which is not the case in most of the eye images due to the eyelid occlusion.

Method 2: Convolutional Neural Network method

We need a lot of data to train our Convolutional Neural Network. If the Hough Circles method, that is used for preparing the data for training, doesn't work very well, we would need to prepare the annotations for a huge number of images. As the CNN method is a regression model and we do not use closed eyelid images for training, the method detects a circular iris for closed or partially closed eyelid images as well. This method also assumes the iris region to be perfectly circular.